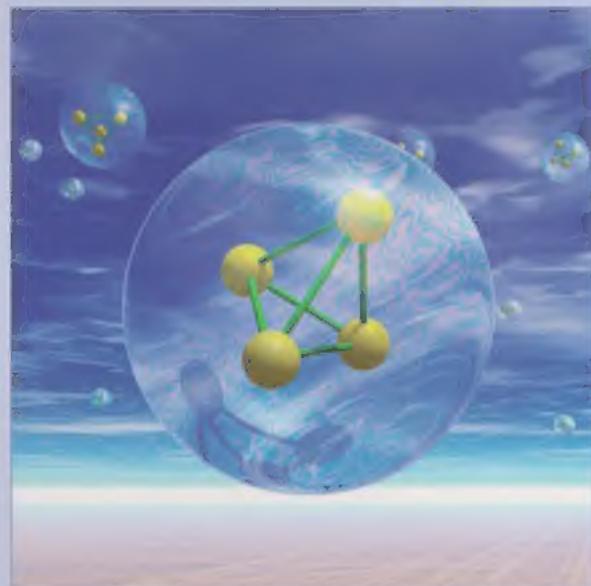




M255 Unit 2
UNDERGRADUATE COMPUTING

Object-oriented programming with Java



Object concepts

Unit 2



M255 Unit 2
UNDERGRADUATE COMPUTING

Object-oriented programming with Java



Object concepts

Unit 2

This publication forms part of an Open University course M255 *Object-oriented programming with Java*. Details of this and other Open University courses can be obtained from the Student Registration and Enquiry Service, The Open University, PO Box 197, Milton Keynes, MK7 6BJ, United Kingdom; tel. +44 (0)870 333 4340, email general-enquiries@open.ac.uk

Alternatively, you may visit the Open University website at <http://www.open.ac.uk> where you can learn more about the wide range of courses and packs offered at all levels by The Open University.

To purchase a selection of Open University course materials visit <http://www.ouw.co.uk>, or contact Open University Worldwide, Michael Young Building, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom for a brochure: tel. +44 (0)1908 858785; fax +44 (0)1908 858787; email ouwengq@open.ac.uk

The Open University
Walton Hall
Milton Keynes
MK7 6AA

First published 2006. Second edition 2008.

Copyright © 2006, 2008 The Open University.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, transmitted or utilised in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without written permission from the publisher or a licence from the Copyright Licensing Agency Ltd. Details of such licences (for reprographic reproduction) may be obtained from the Copyright Licensing Agency Ltd of 90 Tottenham Court Road, London, W1T 4LP.

Open University course materials may also be made available in electronic formats for use by students of the University. All rights, including copyright and related rights and database rights, in electronic course materials and their contents are owned by or licensed to The Open University, or otherwise used by The Open University as permitted by applicable law.

In using electronic course materials and their contents you agree that your use will be solely for the purposes of following an Open University course of study or otherwise as licensed by The Open University or its assigns.

Except as permitted above you undertake not to copy, store in any medium (including electronic storage or use in a website), distribute, transmit or retransmit, broadcast, modify or show in public such electronic materials in whole or in part without the prior written consent of The Open University or in accordance with the Copyright, Designs and Patents Act 1988.

Edited and designed by The Open University.

Typeset by The Open University.

Printed and bound in the United Kingdom by The Charlesworth Group, Wakefield.

ISBN 978 0 7492 5494 0

CONTENTS

Introduction	5
1 Classes and protocols	6
1.1 Frogs and toads	6
1.2 Objects of different classes	8
1.3 Classes and writing software	8
1.4 Polymorphism	9
2 Classes and subclasses	12
2.1 Hoverfrogs	12
2.2 Subclasses	14
2.3 Programming and subclasses	15
3 Message arguments	17
3.1 Messages and arguments	17
3.2 Message names	18
4 Message answers, enquiry messages and collaborating objects	21
4.1 Message answers	21
4.2 Accessor pairs of messages	23
4.3 Collaborating objects	23
4.4 The <i>Frog</i> class	26
5 A bank account class	27
5.1 Creating and inspecting <i>Account</i> objects	29
5.2 Exploring the protocol of <i>Account</i> objects	33
5.3 Collaborating <i>Account</i> objects	34
5.4 Recap of terminology	38
6 Summary	41
Glossary	43
Index	45

M255 COURSE TEAM

Affiliated to The Open University unless otherwise stated.

Rob Griffiths, Course Chair, Author and Academic Editor

Lindsey Court, Author

Marion Edwards, Author and Software Developer

Philip Gray, External Assessor, University of Glasgow

Simon Holland, Author

Mike Innes, Course Manager

Robin Laney, Author

Sarah Mattingly, Critical Reader

Percy Mett, Academic Editor

Barbara Segal, Author

Rita Tingle, Author

Richard Walker, Author and Critical Reader

Robin Walker, Critical Reader

Julia White, Course Manager

Ian Blackham, Editor

Phillip Howe, Compositor

John O'Dwyer, Media Project Manager

Andy Seddon, Media Project Manager

Andrew Whitehead, Graphic Artist

Thanks are due to the Desktop Publishing Unit, Faculty of Mathematics and Computing.

Introduction

This unit builds upon the object concepts introduced in *Unit 1*.

Here we will look further at messages and discuss:

- ▶ how an object's response to a message may depend on the state of its attributes;
- ▶ how some messages need extra information in the form of arguments;
- ▶ how some messages change the state of the receiver, while others simply return a message answer – often the value of one of the receiver's attributes;
- ▶ polymorphic messages – messages that objects of more than one class may respond to, but that might yield different behaviour depending on the class of the receiver;
- ▶ object collaboration – how, once an object is sent a message, that object may then need to send messages to another object(s) to help it carry out the behaviour associated with that message.

We also introduce the **superclass/subclass** relationship between classes, whereby a subclass inherits the protocol and attributes of its superclass but then defines additional attributes and behaviour for its instances. This superclass/subclass relationship is central to object-oriented programming and results in robust and economical code.

Much of your work in this unit will involve practical activities and you will be using a variety of microworlds from the Amphibian Worlds application introduced in *Unit 1*. However, in addition to Frog objects, these microworlds are also inhabited by HoverFrog and Toad objects.

In Section 5 you will also use a simple programming tool, called Accounts World, which has been developed specifically for this unit. In addition to allowing you to write Java code this programming tool will enable you to create objects for the first time (Account objects).

All of the concepts introduced in this unit will be revisited and explored from different points of view in subsequent units.

SAQ 1

What description is given in *Unit 1* for an object?

ANSWER.....

Unit 1 describes an object as a self-contained unit of software that holds data and knows how to process that data. Each object is able to communicate with other objects via messages.

1

Classes and protocols

This section explores the ideas of *class* and *protocol*, which were introduced in *Unit 1*. We also look at the *initialisation* of an object. The term *polymorphism* is defined.

In *Unit 1* you looked at a simple microworld called Two Frogs. In this unit you will explore a whole series of similar worlds, all involving various kinds of amphibian. As we go on we shall gradually introduce additional features designed to illustrate important ideas in object-oriented programming. This may give the impression that the classes concerned are changing; in fact it is simply that the full protocol of the class is only being revealed in stages.

1.1 Frogs and toads

For the next activity you will be using the Amphibian Worlds application and, in particular, its Two Frogs and Toad microworld. This has a new species – toads – represented by **instances** of a new class, Toad. In the microworld, the icons you see are, of course, a graphical representation of Frog and Toad objects. The visual representation of a Toad object in the Graphics Pane is slightly different from that of a Frog object; this reflects the way that the program designer has chosen to portray these objects in the user interface. It is a cosmetic difference that emphasises the different behaviours of Frog and Toad objects. (In a different graphical interface this particular difference in appearance might not be used.)

In Activities 1 and 2 you will be thinking about the class of the Toad objects and the class of the Frog objects.

ACTIVITY 1

Launch the Amphibian Worlds application from your desktop and choose Two Frogs and Toad from the Microworld menu.

- 1 You will see three objects, referenced by the variables `frog3`, `frog4` and `toad1`. For each object, what are the initial values of the attributes `position` and `colour`? (Another way of phrasing this is to ask how each object has been *initialised*.)
- 2 Does `toad1` respond to the message `jump()`? Does `toad1` behave in the same way as the Frog objects (`frog3` and `frog4`)? To find out, select `toad1` and send it some messages. You can do this by clicking the message buttons or writing the Java code in the Code Pane. Try sending the same messages to one of the Frog objects and to `toad1`. Note particularly how the Frog objects and `toad1` respond to the messages `left()`, `right()` and `home()`.
- 3 What evidence is there that the objects `toad1`, `frog3` and `frog4` belong to different classes?

DISCUSSION OF ACTIVITY 1

- 1 When the microworld is first opened, `toad1` is brown and is in position 11, whereas both `frog3` and `frog4` are green and in position 1. In other words, Frog objects are initialised with position 1 and colour GREEN, but the object `toad1` is initialised with position 11 and colour BROWN.

- 2 You saw in *Unit 1* that the objects referenced by `frog1` and `frog2` behave identically in response to the same messages – they are instances of the same class, `Frog`. The indications that the object referenced by `toad1` and the `Frog` objects may belong to different classes lie in the observations that the two kinds of object behave differently in response to the messages `left()`, `right()` and `home()`, and that only the `Frog` objects respond to the message `jump()`.

In response to the messages `left()` and `right()`, the `Frog` objects move position by one unit, whereas the object referenced by `toad1` moves position by two units. The object referenced by `toad1` does not respond to the message `jump()`, whereas the two `Frog` objects jump and land in their original position. On this evidence we suspect that `toad1` does not belong to the `Frog` class.

- 3 The differences observed between `toad1` and the two `Frog` objects are not conclusive evidence that they belong to different classes, but they are sufficient for us to suspect that they do. The implementation of this Amphibian world is, however, that `toad1` belongs to the `Toad` class whereas `frog3` and `frog4` belong to the `Frog` class.

`Frog` and `Toad` objects look slightly different, as the Graphics Pane has been designed to display them differently in order to help the viewer. Their visual representation is distinct from their state. You can tell this, as opening an **Inspector** window on either a `Frog` or a `Toad` object shows that there is no attribute that records what icon should be used to represent it. Unlike the colour and position, the icon used in the Graphics Pane is not part of the object's state.

ACTIVITY 2

The protocol of instances of a class is the set of messages these instances (objects) understand.

In this activity you will once again be using the Two Frogs and Toad microworld in the Amphibian Worlds application.

- 1 Determine as much of the protocol of `Toad` objects as you can by sending each message to the object referenced by `toad1` using the buttons in the microworld. How does this compare with the protocol of `Frog` objects?
- 2 Select `toad1` in the scrollable pane and click on the Inspect button. An **Inspector** window will open on `toad1`. What attributes has the object referenced by `toad1`, and how do these compare with those of the `Frog` objects?

Close any open Inspector windows before proceeding.

DISCUSSION OF ACTIVITY 2

- 1 When you select `toad1` and send it in turn each of the messages given by the buttons in the microworld, you find that it behaves in the following ways in response to the following messages.

`left()` – moves two positions to the left
`right()` – moves two positions to the right
`home()` – moves to (or remains on) the rightmost black 'stone'
`green()` – turns green (unless already green)
`brown()` – turns brown (unless already brown)
`croak()` – croaks audibly (and displays a red '!'')

When any of the messages `up()`, `down()` or `jump()` is sent to a `Toad` object (`toad1`), an error report appears in the Display Pane saying that the object cannot

respond to the message. The messages up(), down() and jump() are not in the protocol of Toad objects.

As already noted, Frog and Toad objects respond to the messages left(), right() and home() in different ways. Neither Frog nor Toad objects respond to the messages up() or down(). The Frog objects respond to the message jump(), but the Toad object does not. From the messages we know about, the protocol for the Toad object contains only left(), right(), home(), green(), brown() and croak().

Although the Toad and Frog objects belong to different classes, behaving differently in response to the messages left(), right() and home(), this does not prevent them from behaving identically in response to some messages, e.g. green() and brown().

- 2 The information displayed in the Inspector window that opens on `toad1` when you press the Inspect button after highlighting the variable `toad1` shows that `toad1` has the same attributes as the Frog objects – position and colour.

Initial state of an object

When the microworld Two Frogs and Toad is opened, it creates one Toad and two Frog objects, each with appropriate state. You saw in the Graphics Pane that the Toad object icon was a different colour and in a different initial position from the Frog object icons – and each icon reflects the state of the corresponding software object. We say that the Toad and Frog objects are **initialised** differently, i.e. their states are different when they are newly created. It is useful to regard a class as something that provides the 'template' for each of its instances.

1.2 Objects of different classes

You have seen that Frog and Toad objects do not have the same protocol, since Toad objects do not respond to the message jump(). Both Frog and Toad objects respond to the messages left(), right(), home(), green(), brown() and croak(). In the cases of the messages green() and brown() the **behaviours** are the same. However, you found that although both Frog and Toad objects respond to the messages left(), right() and home(), their behaviours are different. How a message is interpreted depends on the class to which the object that receives the message belongs.

In inspecting the Frog and Toad objects, you have seen that the variables `frog3` and `frog4` reference instances of the class Frog and that `toad1` references an instance of the class Toad. It is important to distinguish between an instance of a class (for example, `frog1`) and its class (in this case, Frog). The class is the 'factory' for creating instances of the class.

Although Frog and Toad objects have the same attributes, they have different yet overlapping protocols, and behave in a different way in response to some of the same messages. From our discussion of classes in the previous unit, these differences indicate that Frog and Toad objects belong to different classes.

1.3 Classes and writing software

Adopting the idea of **classes** can save a programmer work. One of the goals of software development is to avoid replicating the same code over and over again.

When building object-oriented software, the programmer may have to specify the behaviour of many objects that must collaborate to make some system or program work (for example, the character objects in a word-processed document). In particular, it will be necessary to specify somehow the attributes that each object will have and the messages to which each object will respond.

It would be perfectly possible to build every object afresh from the ground up by providing all the code necessary to specify the attributes and behaviour – but, when a program can involve thousands of objects, this would be unbearably tedious. Moreover we would probably make many errors, and every individual object would need to be tested separately to make sure it was correct. So we look for a way to save effort by writing code only once and reusing it. This is what classes do for us. In any given program you find very often a group of objects that are essentially the same. For example, in a payroll program you would expect to find many objects representing employees. In a drawing program there might be many objects that represent rectangles. When writing a program, whenever you identify that a set of objects all belong to a common classification, with the same attributes and behaviour, you can define a template for this kind of object. The attributes and behaviour will need to be specified just once in the class definition, and then you can use the class to generate an object of that particular kind whenever you like.

Then, however many instances of that class are created, each will automatically have the same attributes and respond to the protocol for the class in the same way, with no additional work on the part of the programmer.

Moreover, once you have tested your code and know it is correct you can rely on all the objects belonging to that class working as intended; you do not need to test them individually.

Of course, different instances of the same class may acquire different states (for example, `frog1` may have its colour attribute set to GREEN, while `frog2` has the value of this attribute as BROWN).

If the attributes or any part of the protocol needs to be changed, the change need be made only once – to the class. The change will automatically apply to all instances of the class.

The idea of class is a key part of object-oriented software development. Identifying common properties at the planning stage, so that objects can be grouped appropriately into classes, enables programs to be written in a concise and economical way.

1.4 Polymorphism

You have seen that Frog objects and Toad objects respond to some messages with the same name, even though they behave differently in response to some of these messages. In fact, it is unusual for two classes to have such similar protocols as these Frog and Toad objects. There are typically major differences in the protocols of any two chosen classes. However, it is not unusual for a particular message to be in the protocol of more than one class. Thus while different classes rarely share exactly the same protocol, it is not unusual for protocols to overlap. Such overlaps can be very useful. To take an example, in the graphical interface in the microworld, the nearly complete overlap of the protocols of the Frog and Toad objects means that they can share the same buttons.

In a word processor it might be helpful if the user could double the size of items such as characters, words, pictures and paragraphs by using one key. A sensible way of organising this in object-oriented software is to have character objects, word objects,

picture objects and paragraph objects (instances of different classes) all understand the message `doubleSize()`.

There is a special term for a message to which objects of more than one class can respond. We say that the message is *polymorphic*. There is no need for the response to be the same for the different classes; in fact it probably will not be. For example, Frog and Toad objects react in their own different ways to the message `home()`. Polymorphic messages are very common in object-oriented programming. You will see later that polymorphism is very useful. Any message to which objects of more than one class can respond is said to be polymorphic or to show **polymorphism**.

Imagine that all the staff in a company have gone to a general staff meeting. At the end of the meeting the speaker says 'Thank you everyone for coming. Now I'll let you get back to whatever you have to do next.'

The members of the audience will understand this and they will each know what to do next. Customer Services staff will go back to dealing with customers, Accounts staff will resume keeping track of accounts, Deliveries staff will continue where they left off arranging deliveries and so on.

Everyone will respond to the same instruction, but they will respond differently according to what department they come from. The speaker does not have to ask each person where they work and then tell them what to do, the speaker does not need to know how to do the jobs, or even what the various jobs are. Each member of the audience will know for themselves what to do without being told.

SAQ 2

In your own words, what does it mean to say that an instance of a class is initialised?

ANSWER

Instances of a class have attributes. It is usual for a newly created object to have its attributes initialised to some initial values. For example the instances of the class `Frog` have the attributes `colour` and `position`. The instances of the class `Frog` are initialised so that the value of `colour` is `GREEN` and the value of `position` is `1`.

SAQ 3

In a certain word processor, characters, words, paragraphs and pictures all understand the message `doubleSize()`, although these objects are instances of different classes. What word is used to describe this kind of situation?

ANSWER

The message `doubleSize()` is polymorphic with respect to instances of the (hypothetical) classes `Character`, `Word`, `Picture` and `Paragraph`.

SAQ 4

Explain the word polymorphism, using an example from the `Toad` and `Frog` classes as an illustration.

ANSWER...

A polymorphic message is a message to which objects of more than one class can respond.

The message `left()` is polymorphic as it can be sent to instances of different classes. All instances of the class `Frog` interpret the message `left()` by subtracting 1 from the current value of their position, whereas instances of the class `Toad` subtract 2 from the

current value. The message `green()` is also polymorphic. It is understood by instances of more than one class for example, `Toad` and `Frog` objects. The behaviour caused by sending `green()` to either a frog or a toad is the same.

It is considered good style to give a message a descriptive name. Although the computer would not care if you used an arbitrary name such as `messageF9B()`, human beings who want to understand the program find meaningful names extremely helpful! The message name `left()`, for example, is descriptive of what it does.

2

Classes and subclasses

We now explore classes and subclasses. We also introduce the term superclass. An object's response to a message sometimes depends on its state when the message is received; this state-dependent behaviour is illustrated in Activity 4.

2.1

Hoverfrogs

In this section you will meet a new species of amphibian – the hoverfrog.

ACTIVITY 3

Launch the Amphibian Worlds application and then choose HoverFrogs from the Microworld menu. In this microworld there are two ~~Frog~~ objects, referenced by the variables `left()`, `right()` and `home()`. (You will see a rotor blade on the head of the graphical representation of each HoverFrog object.)

You will now explore the messages to which ~~Frog~~ objects respond, and how they behave in response to these messages. The results you obtain will help you to decide how HoverFrog objects are related to Frog objects.

- Do ~~Frog~~ objects respond to the same messages and behave in the same way as Frog or Toad objects? To find out, send some messages to the HoverFrog objects and observe the effects.
- What is the protocol of the HoverFrog objects (to the extent shown in this microworld)? Describe the resulting behaviour for each message in the protocol.

DISCUSSION OF ACTIVITY 3

- A HoverFrog object can respond to the same messages to which Frog and Toad objects can respond, and it responds to all of these messages in the same way as a Frog object. In addition a HoverFrog object can respond to messages to which a Frog object cannot respond, namely `up()` and `down()`.
- The protocol for the HoverFrog objects as shown in the microworld HoverFrogs is `left()`, `right()`, `home()`, `up()`, `down()`, `jump()`, `green()`, `brown()` and `croak()`. The usual behaviour of the HoverFrog objects in response to each of these messages is shown below.

`left()` – moves one position to the left

`right()` – moves one position to the right

`home()` – moves to (or remains on) the leftmost black 'stone' (which then turns yellow)

`up()` – moves up by one on the six 'steps' above the stone

`down()` – moves down by one on the six 'steps' above the 'stone'

`jump()` – jumps and lands again on the same 'stone'

`green()` – turns green (unless already green)

`brown()` – turns brown (unless already brown)

`croak()` – croaks audibly (and displays a red 'I')

In the discussion of Activity 3, the descriptions of the behaviour of a HoverFrog object in response to the messages up(), down() and jump() were incomplete. The discussion took no account of the fact that the response to these messages varies according to the state of the HoverFrog object when it receives the message. Exploration of state-dependent behaviour forms the basis of the next activity.

ACTIVITY 4

This activity explores how the behaviour of an object sometimes varies according to the state it has when it receives a message.

Launch the Amphibian Worlds application and then open the microworld HoverFrogs Experiment with the up() and down() messages send each of the messages up() and down() in succession to the same object and note the object's behaviour. Then expand the descriptions given in the discussion of Activity 3 for the behaviour of a HoverFrog object in response to these messages, taking into account the way that this depends on the receiver's state.

In the same way give an improved description of the behaviour of a HoverFrog object in response to the message jump() that takes account of its dependency on the receiver's state.

Can you guess an attribute that Frog objects possess that Tadpoles and Toads objects do not? Make a guess before being tempted to look at the attributes of a HoverFrog object with an inspector.

Select a variable that references a HoverFrog object and press the inspect button. What are the attributes of a HoverFrog object?

Send the up() and down() messages to a HoverFrog object inspecting its state after each message. What sort of values can be held by the attribute that is changing in response to these messages? Is a HoverFrog object initialised identically to a Frog object?

DISCUSSION OF ACTIVITY 4

What is missing in the discussion of Activity 3 is an account of the behaviour of a HoverFrog object when it is at its minimum height (on a stone) and the message down() is sent to it, and when it is at its maximum height and the message up() is sent to it. In both cases no visible action results. Also, when a HoverFrog object is not at its minimum height the message jump() has no visible effect.

up() – moves up by one on the six 'steps' above the 'stone' (unless already at maximum height)

down() – moves down by one on the six 'steps' above the 'stone' (unless already at minimum height)

jump() – jumps and lands again on the same 'stone' (provided it is at minimum height)

HoverFrog objects have attributes colour, position and height

By experimenting with a HoverFrog object and using the inspector you should have discovered that the attribute height only ever holds integer values of 0 to 6.

In the Graphics Pane, HoverFrog objects appear to be initialised identically to the Frog objects. However, this is not strictly correct, as a HoverFrog object has an additional attribute, height, which is initialised to 0.

State-dependent behaviour

You have seen that the way that an object responds to a message may not depend just on its class. It may also depend on its state. In other words, the behaviour of an object in response to a message may be **state-dependent**. This can be illustrated by sending the message `up()` or `down()` to a HoverFrog object. In the microWorld, a HoverFrog object icon in the Graphics Pane does not reflect a response to any message requesting it to go higher than 'step 6' or lower than 'step 0'. This is because the messages that affect the attribute `height` can only give integer values from 0 to 6. So any `up()` or `down()` message to a HoverFrog object that attempted to set the value of `height` beyond these limits left the value unchanged.

2.2 Subclasses

In our particular Amphibian world, Frog and Toad objects have to 'remember' only two things that are changeable: their colour and their position. Hence they have only the two attributes, colour and position, that we considered earlier. In order to be able to respond sensibly to the `up()` and `down()` messages, a HoverFrog object needs an extra attribute `height`. Initialisation of HoverFrog objects is also different in that the `height` attribute is set to 0.

A HoverFrog object can respond to all the messages that a Frog object can respond to, and it behaves in exactly the same way as a Frog object in response to these messages. However, it can also respond to extra messages to which a Frog object cannot respond, namely `up()` and `down()`. Furthermore, as noted above, HoverFrog objects have all the attributes of Frog objects and an additional attribute `height`.

It is clear that there is a relationship between HoverFrog objects and Frog objects. A HoverFrog object can do what a Frog object can do, but more. It has all the same attributes, and more, and this is true for all instances of the Frog and HoverFrog classes. In fact, the programmer took the Frog class as a base and added the extra attribute and protocol required to define the HoverFrog class. The relationship between two such classes is described by saying that the HoverFrog class is a **subclass** of the Frog class, and the Frog class is the **superclass** of the HoverFrog class. The fact that the HoverFrog class is a subclass of the Frog class does not mean that a HoverFrog object is 'less' than a Frog object. The term 'subclass' indicates that the subclass is derived from the superclass. A HoverFrog object has at least the attributes and protocol of a Frog object.

The relationship between the Frog and HoverFrog classes is summarised below.

- The protocol of HoverFrog objects includes that of Frog objects.
- HoverFrog and Frog objects respond in the same way to the messages common to their protocols.
- Instances of the HoverFrog class have the attributes of instances of the Frog class.
- HoverFrog objects have an additional attribute.
- There are messages in the protocol of HoverFrog objects that are not in the protocol of Frog objects.
- The common attributes of the instances of both classes are initialised in the same way.

Not all the points listed above are a necessary part of the superclass/subclass relationship. In later units you will see that it is possible to program a subclass so that its attributes are initialised differently from the corresponding ones in the superclass. You will also see that instances of a subclass may respond to a message in a way that is different from the way instances of the superclass would respond to that message.

A subclass may have a different initialisation from its superclass. It may seem as if Frog and HoverFrog objects have the same initialisation, but this is not strictly true as HoverFrog objects have an additional attribute that has to be given an initial value.

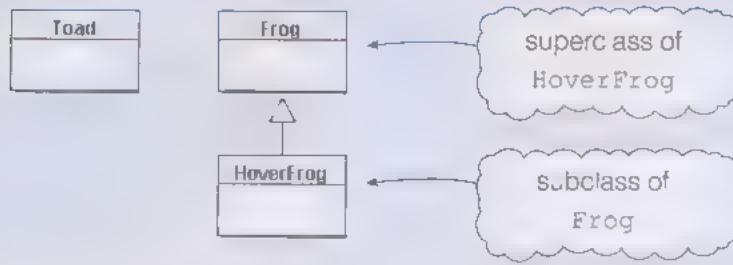


Figure 1 Relationship between the Frog, HoverFrog and Toad classes

The Frog class cannot be a superclass of the Toad class, because instances of Toad cannot respond to `jump()` messages. So could the Toad class be a superclass of the Frog class? Well frogs and toads behave differently in response to `left()` and `right()` messages – in the light of the above discussion, the situation where the Toad class is the superclass of Frog is not precluded but would not be good practice (you will learn more about this in *Unit 6*).

In these discussions we have been looking at views of the way objects relate whilst it would be reasonable to say a hoverfrog *is a* frog we would not normally say a frog *is a* toad or vice versa.

Why is this class/subclass relationship important? Frog objects and HoverFrog objects have aspects of their protocol and attributes in common. As you will see in the next subsection, you need to define these common aspects just once – for the superclass (Frog). Then, the fact that HoverFrog is a subclass of Frog automatically ensures that HoverFrog objects also have this common behaviour.

2.3 Programming and subclasses

Using subclasses when building programs enables you to save on programming effort. When building object-oriented software, the programmer has to specify *what* how the objects of each class will be able to do. But sometimes it turns out that the objects of some prospective class (the HoverFrog objects in our example) need to be able to do everything that objects of some existing class can already do (the Frog objects). In addition, objects of the prospective class may need to be able to respond to extra messages (`up()` and `down()`), and may have extra attributes (`height`). In such a case there is a simple way to save work: the programmer can declare the new class to be a subclass of the existing class (HoverFrog as a subclass of Frog). This ensures that objects of the new class (HoverFrog) have, as a minimum, the same attributes and protocol as the existing class (Frog). This will happen automatically as a consequence of declaring the new class (HoverFrog) to be a subclass of the existing class (Frog). The subclass HoverFrog is said to *inherit* these attributes and this protocol from the superclass Frog. All the programmer needs to do subsequently is to determine any additional attributes (`height`) and messages (`up()` and `down()`) for the subclass.

SAQ 5

Which word or phrase best fits in the following sentence?

The protocol of a HoverFrog object ... the protocol of a Frog object.

- (a) is part of
- (b) is similar to
- (c) includes

ANSWER

The missing word is **includes**. (HoverFrog is a subclass of the class Frog. The instance protocol of HoverFrog includes the protocol of Frog. As you have seen, HoverFrog objects understand some additional messages to which Frog objects do not respond)

SAQ 6

What criteria do you think the programmer has applied in deciding to create the class HoverFrog as a subclass of the class Frog?

ANSWER

The programmer required the instances of the class HoverFrog to have all the attributes of the class Frog to respond to all the messages of the instances of the class Frog and to behave in an identical way in response to most of these messages.

3

Message arguments

This section introduces message arguments, which allow the sender to include information in messages.

3.1 Messages and arguments

Messages become a much more powerful mechanism when you allow them to include extra information. For example, previously there were separate messages for turning an object green or brown. A message that sets the colour of an object and allows you to state the colour required allows a much more general approach. When a message requires extra information for it to make sense, each required piece of information is called an **argument** of the message.

In previous worlds we have made it possible for you to send messages with arguments through the use of menus. When some more information is required from the user after a button is pressed a menu will be presented. You must choose an item from the menu before the message triggered by the button can be sent. In Activity 5 you will meet the `setColour()` button that presents a menu of colours from which one is chosen as the message argument. The use of an argument makes available a wider choice of colours than previously.

ACTIVITY 5

From the Amphibian Worlds application open the microworld Frog & HoverFrog. This microworld contains three new buttons, `setColour()`, `upBy()` and `downBy()`. These buttons are *menu buttons* – in each case a menu will be displayed when the button is pressed. You need to make a choice from the menu. (Remember to highlight a variable referencing a frog or hoverfrog before sending a message.)

- 1 Explore the `setColour()` button by using it to send messages to the `Frog` and `HoverFrog` objects.
Do objects of both classes respond to ? Which colours are available?
- 2 Send messages using the `upBy()` and `downBy()` buttons.
Do both kinds of object respond to a press of these buttons? What information do you have to supply before an object will hover?
- 3 On the screen you can see more of the protocol of the `Frog` objects. What is the name of the additional message that has been revealed in this activity? What is the protocol of `Frog` objects, as revealed in this and previous activities?

DISCUSSION OF ACTIVITY 5

- 1 Both the `HoverFrog` and `Frog` objects understand the message sent by pressing the `setColour()` button. Before you can send a message using one of the `upBy()`, `downBy()` or `setColour()` menu buttons, you have to provide some information. The menu for the `setColour()` button offers a choice of colours: `OUColour.BLUE`, `OUColour.BROWN`, `OUColour.GREEN`, `OUColour.PURPLE`, `OUColour.RED` and `OUColour.YELLOW`.

- 2 Only HoverFrog objects respond to a press of the upBy() or downBy() buttons. The menus for the upBy() and downBy() buttons offer a choice of 1, 2, ..., 6. These determine how many 'steps' up or down you want a HoverFrog object to move.
- 3 The protocol of the Frog objects is the set of messages that the objects understand. You can now see that the message name setColour() is in the protocol of Frog objects. The protocol of Frog objects as revealed in this activity is left(), right(), home(), jump(), green(), brown(), croak() and setColour(). Frog objects do not know how to respond to messages for hovering.

Some books call an argument a **parameter**

Each piece of information you supplied is called a *message argument* (or just *argument*). When an argument is required for a message that a button sends, a menu is presented

The equivalent Java code of selecting the button setColour() and choosing OUColour.RED has the textual form setColour(OUColour.RED). You supply extra information between the brackets of the message because messages always require information to be specified before they can be sent. It is not possible to end such a message without providing the information. The information (here a chosen colour) forms an integral part of the message

You may have been wondering what arguments such as OUColour.GREEN and OUColour.RED are, exactly. Well, we have created a set of OUColour objects for you to use. These objects are held by the OUColour class as *class variables*. All you need to know now is that to get hold of one of these ready-made colours, you just type the name of the class, followed by a full stop and then the colour you want (in capitals) for example, OUColour.YELLOW

13.2 Message names

We have said that when a message contains an argument, the message is incomplete until an argument is chosen. Thus left() is a message, whereas setColour() is not a message until an argument is provided. That means that it is not accurate to talk about 'the message setColour()', since this will not be a message until you pick a particular argument. But what if you want to talk about the entire family of messages represented by setColour(), irrespective of the choice of a particular argument? It would be helpful to have words to make this distinction.

The term **message name** is used for this purpose. For example, the message name for the message setColour(OUColour.RED) is setColour()

The phrase 'message name' is also used with a message that does not take an argument. In this case, the distinction between message and message name is less obviously useful, but the distinction still exists. So, for example, you might say either of the following

'Frog objects understand the message left().'

'I sent a message to a Frog object using the message name left()'

Thus the message name for the message setColour(OUColour.PURPLE) is setColour(), while the message name for the message left() is just left().

In summary, a message is something you send, but a message name is the name of a message or family of messages. So, when we give the instance protocol of HoverFrog as left(), right(), home(), up(), down(), jump(), green(), brown(), croak(), setColour(), upBy() and downBy(), we are giving the protocol in terms of message names

You will learn about class variables in Unit 7.

SAQ 7

- (a) What is the message name in the message setColour(OUColour.YELLOW)?
- (b) What is the message name in the message jump()?

ANSWER

- (a) setColour()
- (b) jump()

SAQ 8

What is the message name in each of the following?

- (a) frog1.setColour(OUColour.BROWN)
- (b) hoverFrog2.green()

ANSWER.....

- (a) setColour()
- (b) green()

ACTIVITY 6

If the microworld Frog & HoverFrog is not open, open it now.

In the Java programming language there is a convention for supplying arguments. Where a message requires an argument you write the message name followed by the argument in the brackets that always follow

```
setColour(OUColour.RED);
```

In the Code Pane, to send a message to change the colour of an object it is necessary first to type the name of the variable referencing the receiver, then a dot, and then the message name with the argument in brackets, followed by a semicolon. For example

```
frog5.setColour(OUColour.RED);
```

Then press the Execute button.

Try sending some colour-changing messages to both frog5 and hoverFrog3 using the Code Pane. If you make a mistake and obtain an error report in the Display Pane, clear the Display Pane by pressing the Clear button and then check the spelling, spacing and capital letters in your typing. (Colour objects have names in upper-case letters and must be preceded by OUColour.)

Type frog5.setColour(); with the argument omitted and press the Execute button. You will see that the error report appears in the Display Pane.

DISCUSSION OF ACTIVITY 6

The objects referenced by frog5 and hoverFrog3 should have changed colour in accordance with the messages you sent.

ACTIVITY 7

To make `HoverFrog` hover using the message `upBy()`, an argument has to be supplied, the argument here is a number chosen from the integers 1 to 6.

So the following is typed in the Code Pane to form a message asking `HoverFrog` to move up two 'steps', i.e. by two units:

```
HoverFrog upBy 2;
```

Send this message. Check that your typing matches the above exactly, taking particular care with the spacing, semicolon and capitalisation, before pressing the Execute button.

Try sending several versions of the same message with other arguments, and also try sending some messages using `downBy()`.

What is the protocol of `HoverFrog` objects as revealed in this and previous activities?

DISCUSSION OF ACTIVITY 7

The protocol of `HoverFrog` objects as revealed in this activity is `left()`, `right()`, `home()`, `up()`, `down()`, `jump()`, `brown()`, `green()`, `croak()`, `setColour()`, `upBy()` and `downBy()`.

SAQ 9

What is the difference in general between a message and a message name? What is the difference between a message and a message name when the message has no arguments?

ANSWER

A message name is the textual form of a message except that any arguments it takes are enclosed in parentheses. The message and the message name are otherwise indistinguishable.

SAQ 10

What is the message name in each of the following?

- (a) `oldBicycle.remove(bell)`
- (b) `oldBicycle.remove(bell, newBicycle)`

ANSWER

- (a) `remove()`
- (b) `remove()`

4

Message answers, enquiry messages and collaborating objects

We start this section with two activities that look at answers generated in response to some messages. We then look at accessor messages dealing with between a message that modifies the state of an object and a message that interrogates the object's state. We conclude this section by discussing collaborating objects and sequence diagrams.

4.1

Message answers

In the following activities you will explore messages that request information from the receiver. These activities show that message answers can be used by objects that need to collaborate (typically to share information).

ACTIVITY 8

From the Amphibian Words application open the Three Frogs microworld. The Graphics Pane in this microworld shows representations of three **frog** objects.

... and has two new buttons **labelled getColour()** and **sameColourAs()**. You will see that some messages result in a message answer, but some do not.

Select a **frog** object and send it the message **getColour()** by pressing the button labelled **getColour()**. Look at the text in the Display Pane and make a note of what you read.

Now send the same object the message **setColour(OUColour.GREEN)** using the button **labelled setColour()** and look at the Display Pane. Has any text been added?

Use the Code Pane to type and execute some similar examples. Look in the Display Pane after each line has been executed.

What are the differences in the behaviour of the **frog** objects in response to messages with names **getColour()** and **setColour()**?

DISCUSSION OF ACTIVITY 8

When the **getColour()** button is pressed, some text describing the colour of the selected Frog object, for example **OUColour.GREEN**, appears in the Display Pane. The message **getColour()** seems to be asking the receiver frog 'What is the value of your colour attribute?' and the message is answered. Similarly, if you type **frog6.getColour()** in the Code Pane, the Display Pane shows the text **OUColour.GREEN**.

What you see in the Display Pane is a textual – as opposed to a graphical – representation of the message answer returned in reply to the message. Hence, for example, you will see the text **OUColour.GREEN** rather than a patch of greenish hue.

When a Frog object is sent the message **setColour(OUColour.RED)** it responds by changing its colour attribute to **OUColour.RED**, and nothing appears in the Display Pane. A **setColour()** message does not return an answer.

In contrast, the message **getColour()** does not change the state of the receiver; it returns as the message answer the value of the attribute **colour**.

ACTIVITY 9

We shall now ask you to examine the sameColourAs() menu button and the message named sameColourAs() in the microworld Three Frogs.

The sameColourAs() button is used to send a ~~sameColour()~~ message to a Frog object requesting it to change its colour to the same colour as another Frog, Toad or ~~another~~ object. The argument specifies the object from which you want the receiver to take its new colour.

- 1 Select the variable frog6 and press the button labelled green().
Select the variable frog7 and press the button labelled brown().
- 2 Select the variable , press the button labeled sameColourAs() and select the variable frog7 from the menu. This sends the message sameColourAs(frog7) to the selected receiver. You can use the button labelled setColour() to send messages to the three objects so that each is a different colour again. Practise sending similar messages.
- 3 Now use the Code Pane to send messages to the three objects so that each is a different colour. For example the following lines, on execution will change the colour of frog6 to purple and frog7 to brown.

```
frog6.setColour(OUColour.PURPLE);
frog7.brown();
```

Now type a line in the Code Pane similar to the one below and execute it.

```
frog6.sameColourAs(frog7);
```

- 4 Send other messages using the sameColourAs() message name.

DISCUSSION OF ACTIVITY 9

In part 2 the receiver changed colour to that of the Frog object specified as the argument to message ~~setColour()~~. For example, frog6 changed from green to brown in response to the sameColourAs(frog7) message. In part 3 you used the Code Pane to send setColour() and sameColourAs() messages.

For one object (frog7, for example) to be used as an argument for a message to another object (frog6, for example) involves the *collaboration* of the argument object and the receiver.

SAQ 11

What is the protocol of Frog objects as revealed in the microworld Three Frogs?

ANSWER

The protocol of Frog objects as revealed in this activity is left(), right(), home(), jump(), green(), brown(), croak(), setColour(), getColour() and sameColourAs()

14.2 Accessor pairs of messages

The message `getColour()` has a different purpose from the previous messages you have seen. In sending the message `getColour()`, you are not interested in changing the state of the receiver object. Instead you are interested in obtaining information about its state.

When the message `getColour()` is sent to a `Frog` object, it replies with information about its colour. The requested information is returned as the **message answer**. In sending this message, you ask the `Frog` object for the value of its `colour` attribute. It is usual to say that the message `getColour()` 'returns the colour of the receiver'. In sending the message `setColour(OUColour.RED)` to a `Frog` object, you request the receiver to set its attribute `colour` to `OUColour.RED`. Note that you are not requesting an answer, and no answer is given.

It is common in this way for the protocol for an object to include pairs of messages: one that gets the value of an attribute of the receiver object, and one that allows that attribute to be set. A **getter message** and the corresponding **setter message** (as the get and set messages are termed) together form what is called a pair of **accessor messages**. In our example we have `getColour()` and `setColour()`, where `getColour()` is the getter message name and `setColour()` the setter message name.

A message answer is sometimes called a message reply

SAQ 12

What, if anything, is returned as the message answer when you send the following messages to a `Frog` object that is brown and is on the leftmost 'stone'?

- (a) `getColour()`
- (b) `setColour(OUColour.RED)`

ANSWER

- (a) `OUColour.BROWN`
- (b) No answer is returned.

14.3 Collaborating objects

The message `right()` sent to a `Frog` object requests a straightforward response from the receiver object: no other objects are involved. Often, however, before an object can act on a message it has to collect some information from another object or objects; it does this by sending them messages. The required information comes back as answers to the messages sent, enabling the object to deal fully with the initial message. In such cases, several objects are 'collaborating' by sending messages to each other. (This is not the only form of collaboration; some objects might collaborate by taking responsibility for particular bits of required behaviour.)

Message answers can also provide information that is to be used with a later message. Sometimes the information is the value of a particular attribute of an object. For example, if a `Frog` object needs to know the colour of another `Frog` object, it would have to send the other `Frog` object a message and the information would be returned as the message answer. There is no reason why message answers should not be used as message arguments in subsequent messages.

Two `Frog` objects **collaborate** when `frog1.sameColourAs(frog2)` is executed, as described below.

The message named `sameColourAs()` when sent to a `Frog` object requests it to change its colour to be the same as another `Frog` object. The argument for `sameColourAs()` specifies the `Frog` object from which the receiver takes its new colour. There is nothing new about asking a `Frog` object to change its colour, but in all previous cases the message indicated explicitly what the new colour should be – as in the message `setColour(OUColour.RED)`. However in using the message named `sameColourAs()`, an argument specifies another `Frog` object that has the required information (as the value of its attribute `colour`).

A technique that is often used to follow a sequence of messages between collaborating objects is to put yourself in the place of the receiver of the message. To follow the sequence of messages when the message `sameColourAs(frog2)` is sent to `frog1`, this technique requires you to put yourself in the place of `frog1`. You are asked to use this important technique in Exercise 1.

Exercise 1

Imagine that you are the object `frog1`. If you as `frog1` are sent the message `sameColourAs(frog2)` describe informally the messages you would have to send and the answers you would use in order to satisfy this request.

Solution.....

As `frog1`, you have been asked to change your colour to the same colour as `frog2`. Now as a human you, of course, see the colour of `frog1` by looking at the graphical interface provided. But, as `frog1`, you have no way of 'seeing' such information. The only way that you, as `frog1`, can find out that colour is to send the message `getColour()` to `frog2`. The colour will be provided to you, as `frog1`, as a message answer. Now you are nearly, but not quite, finished.

You, as `frog1`, still need to change your own colour to the colour given by the message answer. But you cannot just effect this by magic. As you know, the only way you can get an object to do anything is to send it a message. This is often the best way to achieve something even when the object in question is you. Hence the sensible way for you, as `frog1`, to change your own colour in line with the message answer is to send yourself the message `setColour()` using as argument the colour you got from `frog2` as a message answer. (The message named `setColour()` is used with an argument to request the receiver object to change colour.)

Sending a message to yourself may seem a strange way for an object to behave, but this is in line with the rules by which objects communicate. Nothing forbids an object sending a message to itself. Often it's the simplest (and sometimes the only) way for an object to get something done.

The interaction between the objects when the statement `frog1.sameColourAs(frog2);` is typed into the Code Pane by a user and then executed can be seen in diagrammatic form in Figure 2. This kind of diagram is sometimes known as a **sequence diagram**. The user generates the chain of messages and will see an effect in the form of a change to the visible `frog1` icon. It is the collaborations between the software objects, rather than between the user (you) and user interface, that are important here.

In Figure 2, vertical lines called lifelines represent the objects named above them; solid arrows represent messages from sender to receiver, and dashed arrows represent message answers. Time runs vertically downwards. It is assumed that the attribute `colour` of `frog2` has the value `OUColour.GREEN`.



Figure 2 A sequence diagram

Exercise 2

Answer Exercise 1 again using Figure 2 this time stating more formally the messages that `frog1` would have to send on receipt of the message `sameColourAs(frog2)` and what message answers would be involved. Assume that the attribute `colour` of `frog1` has the value `OUColour.GREEN`.

Solution

On receipt of the message `sameColourAs(frog2)`, `frog1` sends the message `getColour()` to `frog2`. The answer to this message is `OUColour.GREEN`. Now `frog1` sends the message `setColour(OUColour.GREEN)` to itself.

In order to get the desired effect, the message answer from the first message is used as the argument to the second message.

In Figure 2, the messages sent from one object to another are shown in order down the page. The messages are ordered from top to bottom. Reading from top to bottom, the sequence is as follows:

- The user (you are no longer `frog1`!) sends the message `sameColourAs(frog2)` to `frog1`.
- `frog1` sends the message `getColour()` to `frog2`.
- `frog2` returns as the message answer the value of its attribute `colour` (`OUColour.GREEN`) to `frog1`.
- Finally, `frog1` sends itself the message `setColour(OUColour.GREEN)`, where the argument `OUColour.GREEN` is the message answer from the previous message.

In the above example, the user sends a single message `sameColourAs(frog2)` to `frog1`. The message causes `frog1` to respond by sending two messages in turn. The first of these messages is to `frog2` and has the purpose of eliciting information in the form of a message answer and the second is to itself. The user does not directly specify the new colour for `frog1`; rather `frog1` had to ask `frog2` for the information. Then `frog1` changes its own colour (by sending a message to itself). In this example, the user

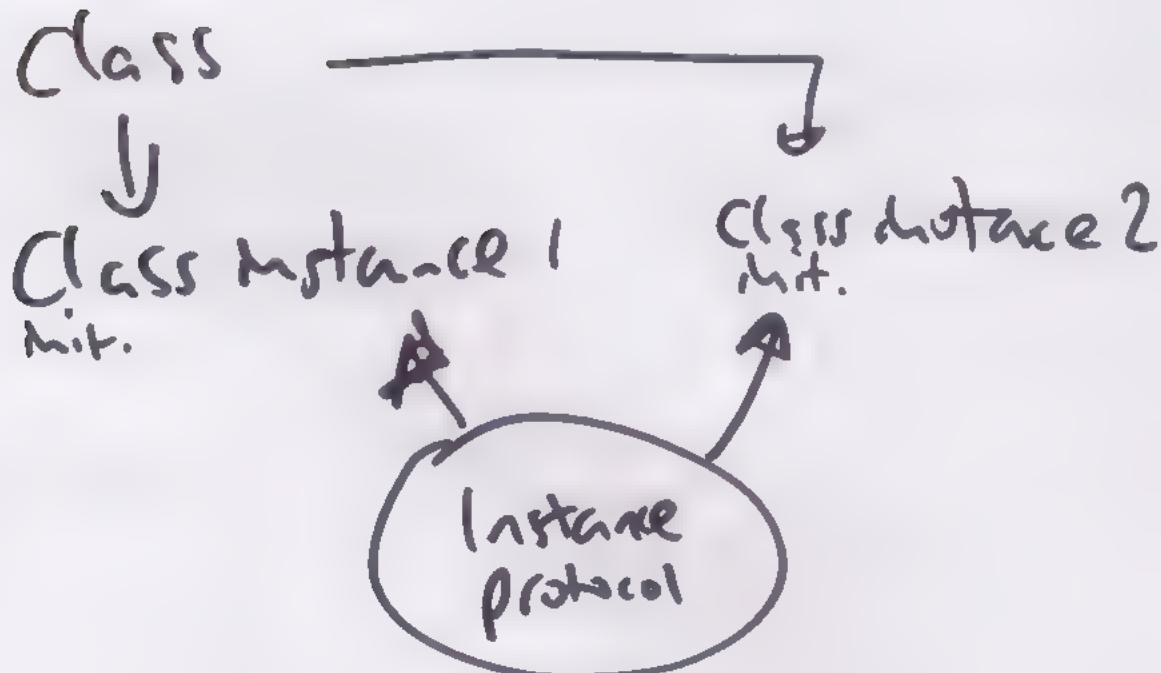
caused a `Frog` object to send a message to another `Frog` object. The two `Frog` objects worked together in order to do something you (the user) requested. This is an example of **collaborating objects**

14.4 The Frog class

Before proceeding to another scenario, we shall summarise the key features of a class in terms of the `Frog` class.

A class groups together objects that the programmer considers to be similar. Instances of the same class respond to the same set of messages (the instance protocol) have the same attributes and respond in the same way to each message

All instances of the class `Frog` are created with the same attributes `colour` and `position`, but each `Frog` object is an 'individual' in that the values of its attributes belong to itself. So `frog1` may have `position` as 1 and `colour` as `OUColour.BROWN` whereas the attributes of `frog2` may have the values 2 and `OUColour.BLUE`. The protocol for the `Frog` objects is defined in the class `Frog`, so all instances understand the messages `left()`, `right()`, `home()`, `jump()`, `brown()`, `green()`, `croak()`, `getColour()`, `setColour()` and `sameColourAs()`, and respond in the same way to each message. The initialisation of each instance is also defined in the class `Frog` so that each `Frog` object is initialised with the value of `position` as 1 and the value of `colour` as `OUColour.GREEN`



5

A bank account class

In this section we reinforce the notions of object, message and message answer by using them in an everyday situation.

This is done with reference to a particular application: a simple banking system, which is designed to handle very basic bank accounts. Such an account will normally require a certain amount of information to be associated with it. In this example the accounts are very simple and the only information they will store will be the name of the account holder, the account number and the current balance. These accounts will be modelled using Account objects, one object for each customer. An Account object will have the following attributes: holder, number and balance. Figure 3 shows how such an Account object can be represented by an **object-state diagram**.

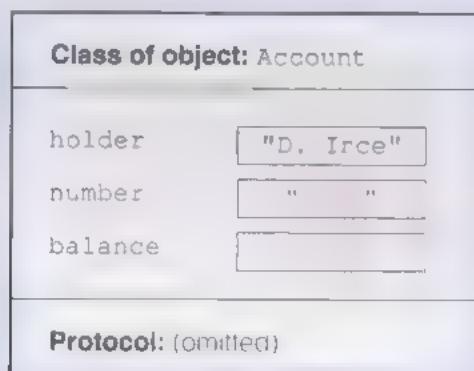


Figure 3 An object-state diagram of an Account object

The object shown in Figure 3 has attributes holder, number and balance and each currently has a value – "D. Ince", "2011" and 12.6, respectively. Note that account numbers are treated as textual rather than as numeric quantities.

The diagram reflects the fact that this object belongs to a class called Account. There is space in the diagram for the protocol of the object, i.e. a listing of the messages to which the class Account objects can respond. The space for the protocol is blank for now; later in this unit you will discover what messages an Account object can understand.

A banking system can be modelled (in part) as a set of Account objects, each of which corresponds to someone's account with the bank. Some means of referring to each Account object is required. A solution would be to have suitably named variables each referencing an account object, just as was done earlier with Frog objects. The Account object represented by Figure 3 can be referenced by a variable called e.g. myAccount. That this particular variable refers to a particular object is symbolised in Figure 4 by means of an arrow pointing from the variable name to the object.

Note the use of a capital A in the middle of the variable name myAccount. This convention is common in programming when a variable name or message name is composed of two or more English words, or abbreviations, the first word starts with a lower-case letter, and a single upper-case letter is used to mark the start of each subsequent word.

Always take care with capitals when typing, since Java distinguishes between upper-case and lower-case letters.

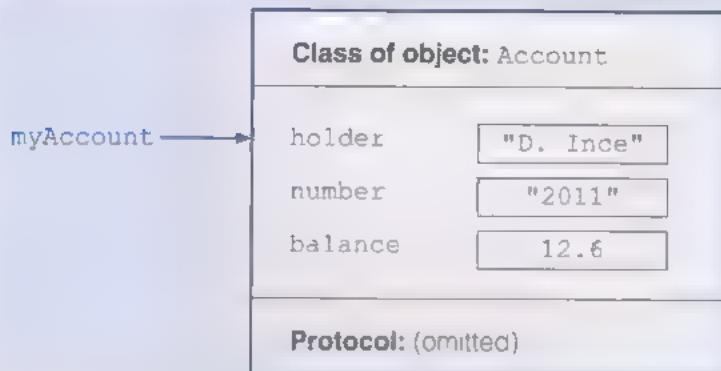


Figure 4 A named Account object

You will carry out the activities in this section using a simple programming tool for Account objects called Accounts World, which allows you to create new Account objects, and to send messages to them.



Figure 5 The Accounts World programming tool

The Accounts World has three panes. The top pane in the Accounts World is called the Code Pane. This is where you type statements that you want to be executed. Statements are not executed until they have been highlighted (selected) and their execution requested by choosing Execute Selected from the Action menu. To the right of the code pane are two buttons. The button labelled Add Account is used to create Account objects (you will be prompted for a variable name when you click this button). The other button, labelled Protocol, is used to open another window, which you can use to get information on the protocol of Account objects.

Below the Code Pane there are two further panes. On the left there is the Display Pane. This has two functions. Firstly, it is where the Accounts World's Java interpreter will write any error messages if you make a mistake in any statement(s) you are testing in the Code Pane. For example, if you attempt to send a message to an Account object, which is not in its protocol (such as misspelling the `getBalance()` message), we encounter

later, as `getBalance()`) the Java interpreter that is used to parse and execute code in the Code Pane will write Semantic error: Message `getBalance()` not understood by class 'Account' in the Display Pane. The second function of the Display Pane is to display the value of the last expression evaluated in a statement (or series of statements). This will occur only if you check the Show Results check box. To the right of the Display Pane is the Variables Pane. This pane will display any variables declared in the Code Pane.

Remember that when you close the Accounts World any objects you created will be lost.

5.1

Creating and inspecting Account objects

Most of your study time in this subsection will be taken up with practical activities.

These activities are intended to give you a flavour of how objects and messages can be used to represent an everyday situation: the use of bank accounts. In the Amphibian microworlds you worked with objects that had already been created for you; here you will create new objects and send messages to them. In doing so, you will be introduced to terminology about code in Java that will be very important later in the course.

Typing and dealing with errors

You may find that unexpected problems arise when you try to execute code that you have typed. This is often the result of incorrect typing. To help avoid these errors you may like to read the following guide and return to it if you receive error reports.

Error messages may result from Java not understanding what you have typed in when you try to execute the code, or from a typing error causing you apparently to ask Java to send a strange message to a strange object. The error messages displayed in the Display Pane may not always make much sense, but do not worry – in the majority of cases, the solution can be found among the following points, which you should glance over before you start. So take note of the following tips before typing into the Code Pane or when you get an error message in the Display Pane.

- 1 Check spelling, capitalisation (or its absence), spaces and punctuation. All of these can alter the meaning of a variable name or message.
- 2 Make sure you are selecting the desired text, the whole of the desired text and nothing but the desired text when you execute it.
- 3 By convention all message names begin with lower-case letters, but message names may include upper-case letters (e.g. `getNumber()`).
- 4 Use the Variables Pane to check you are using the name of the variable referencing the Account object exactly as you declared it when you created it. You may have typed it in differently from the way it appears in this text. In particular, check spelling and capitalisation.
- 5 When you are creating a new Account object, you are asked to supply a name for a variable to reference it. Make sure that the name contains no spaces.
- 6 Use the protocol for the Account class to check you are spelling message names correctly.
- 7 Later, you will meet messages with multiple arguments. There should be commas separating multiple arguments. Java does not require a space after such a comma and before the following argument, but please include one for clarity.

ACTIVITY 10

Here you are going to create a new `Account` object, referenced by a variable called `myAccount`. In the Accounts World click on the Add Account button. In the window that opens you will need to give the name for a variable to reference the new object. Use the name `myAccount` (be careful about capitalisation) and then press the OK button.

This creates a new `Account` object referenced by the variable named `myAccount`. You have now created an `Account` object, but you do not know yet what state it is currently in. A quick way to find out is to use an inspector. To examine the state of the object referenced by `myAccount`, double-click its variable name in the Variables Pane. An Inspector window will be opened on the newly created `Account` object. Use the Inspector window to answer the following two questions.

- 1 What is the initial state of the object referenced by `myAccount`?
- 2 Has the name of the variable `myAccount` had any effect on the value of the `holder` attribute of the object?

When you have finished, close the Inspector window.

Keep the Accounts World open as the `Account` objects will be used in the next activity.

DISCUSSION OF ACTIVITY 10

When you created your new `Account` object you should have seen the name of the variable you created appear in the Variables Pane.

- 1 The holder and number attributes of the new `Account` object are given as "" (the empty string). The balance is given as 0.0. When an `Account` object is created its attributes are always initialised in this way.
- 2 As the Inspector shows, the name of the variable referencing an `Account` object and its holder have no connection – they are entirely different things.

ACTIVITY 11

You have created an `Account` object, but to change its state, or get it to do anything else, you will need to send it messages. In our banking system, an account belongs to someone (represented by the `holder` attribute of an `Account` object) and the account has an account number and current balance. To make a start, you are going to make the holder of the account be someone named "Grendel Party", with an account number of "1234", and you are going to credit the account with a sum of 100.

Return to the Accounts World, and send the message `setHolder("Grendel Party")` to `myAccount` (taking care not to forget the quotes). That is, you will need to type in the Code Pane the following.

```
myAccount.setHolder("Grendel Party");
```

To execute the message, select it and right-click, and choose the menu item Execute Selected. Recall, from *Unit 1*, that this is known as a **message-send** and consists of a receiver (the object being sent a message) followed by a full stop and then a message. In the above expression, the receiver is the object referenced by `myAccount` and the message is `setHolder("Grendel Party")`.

Then type in and execute the message-send

```
myAccount.setNumber("1234");
```

and then

```
myAccount.setBalance(100);
```

Inspect `myAccount` and note what you see.

DISCUSSION OF ACTIVITY 11

When you double-clicked `myAccount`, an inspector was created that showed the current state of the `Account` object referenced by the variable `myAccount`. As a result of your messages the inspector should report that the holder is "Grendel Barty", the number is "1234" and the balance is 100.0.

ACTIVITY 12

In the Accounts World, create two more `Account` objects. In particular create a new `Account` object referenced by a variable called `hisAccount` (for the holder "Everest Grundy", who has an account number of "2468") and credit it with 200. Then create a new `Account` object referenced by a variable called `herAccount` (for the holder "Lucy Nijholt", who has an account number of "1111") and credit it with 300. After you have sent these messages inspect each of the two objects to check that its subsequent state is what you expect.

Keep the Accounts World open as the `Account` objects will be used in the next activity

DISCUSSION OF ACTIVITY 12

Creating the new accounts in the Accounts World is just an affair of clicking on the Add Account button, and providing a variable named `hisAccount` (or `herAccount`) for the `Account` object you want to create. When you have clicked on OK, the `Account` object is created. You should then see the variable name `hisAccount` (or `herAccount`) appear in the Variables Pane.

Once you have created the accounts, the message-sends you should have executed are given below.

```
hisAccount.setHolder("Everest Grundy");
hisAccount.setNumber("2468");
hisAccount.credit(200);
herAccount.setHolder("Lucy Nijholt");
herAccount.setNumber("1111");
herAccount.credit(300);
```

Inspecting your newly created objects should confirm that the object referenced by the variable `hisAccount` is held by "Everest Grundy", with a number of "2468" and a balance of 200.0; and that the object referenced by the variable `herAccount` is held by "Lucy Nijholt", with a number of "1111" and a balance of 300.0.

Exercise 3

The only way you have seen to make an object do anything (even to divulge its state) is to send it a message. But in the practical activity above you managed to use an inspector to find out the state of an object referenced by variable `myAccount` immediately after it was created, without apparently sending any message to `myAccount`. Using what you know about objects, can you think of a straightforward explanation of what happened when you used an inspector to find out the state of `myAccount`?

Solution.....

Double-clicking a variable name creates an inspector, which is itself an object. It was the Inspector object that sent a message to `myAccount` to find out its state, and then displayed the result. Hence it still holds true that the only way to find out the state of an object is to send it messages.

Exercise 4

You have seen how **message-sends** consist of a receiver and a message. In the practical work you have also constructed message-sends with arguments, as in `myAccount.setHolder("Grendel Barty")`. In this case the message is composed of a message name, `setHolder()`, and an argument, "Grendel Barty".

For each of the message-sends `myAccount.setNumber("1234")` and `myAccount.credit(100)`, identify the receiver, message name, argument and message.

Solution.....

For the message-send `myAccount.setNumber("1234")`

- ▶ `myAccount` is the receiver,
- ▶ `setNumber()` is the message name,
- ▶ "1234" is the argument,
- ▶ `setNumber("1234")` is the message

For the message-send `myAccount.credit(100)`

- ▶ `myAccount` is the receiver
- ▶ `credit()` is the message name,
- ▶ 100 is the argument,
- ▶ `credit(100)` is the message

SAQ 13

What is the connection between the name of the variable used to reference an Account object and its holder?

ANSWER

There is no connection. If you had an Account object that was referenced by the variable `thisAcc` and whose holder was "J. Bloggs", you could still reference this object using `thisAcc` while sending a message to change the holder to "Mary Brown".

SAQ 14

Which of the following is true?

- An object may be referenced by at most one variable
- An object must be referenced by exactly one variable.
- An object could be referenced by several variables.

ANSWER

- False
- False
- True

5.2 Exploring the protocol of Account objects

As in the previous subsection, most of your work here will consist of activities.

Now that you have three Account objects this is a good time to explore some more of the Account protocol.

ACTIVITY 13

Go to the Accounts World and explore the protocol for the Account class. To do this, click on the Protocol button – this will open a window displaying information about the `Holder` message. On the left-hand side of the window is a set of buttons labelled with the names of the messages in the protocol of Account objects; clicking one of these buttons will then display the information (documentation) for that message – what it does, what arguments it takes and what value (if any) it returns.

You can now turn your attention to changing the state of an Account object – namely that referenced by the variable `herAccount`. (If you had previously closed the Accounts World then you will need to create an Account object referenced by the variable `herAccount`, and set the balance of the account to 1000.) Send messages to perform the actions listed below, in the order given, by entering the relevant code in the Code Pane. After sending each message, look in the Display Pane at the textual representation of any message answer that is produced.

- 1 Use the message `Holder`, to check that the holder of the account referenced by the variable `herAccount` is "Lucy Nijholt".
- 2 Debit 100 from Lucy's account.
- 3 Use the message `getBalance()` to check the resulting balance.
- 4 Set the number of Lucy's account to "2000".
- 5 Send a message to check the account number of Lucy's account.
- 6 Debit 3000 from Lucy's account.
- 7 Use the message `Holder` to check the resulting balance of Lucy's account.

Draw an object-state diagram to depict the object referenced by `herAccount` and its current state. Add the names of the messages you have used so far to the Protocol section of the diagram.

DISCUSSION OF ACTIVITY 13

The corresponding Java code and message answers are as follows:

- 1 `herAccount.getHolder();`
(the textual representation of the message answer is "Lucy Nijholt")
- 2 `herAccount.debit(100);`
(the textual representation of the message answer is true).
- 3 `herAccount.getBalance();`
(the textual representation of the message answer is 200.0).
- 4 `herAccount.setNumber("2000");`
(there is no message answer).
- 5 `herAccount.getNumber();`
(the textual representation of the message answer is "2000")
- 6 `herAccount.debit(3000);`
(the textual representation of the message answer is false).
- 7 `herAccount.getBalance();`
(the textual representation of the message answer is 200.0)

A debit() message returns the answer true if the transaction has been actioned (because the balance represents sufficient funds) and false if it has not been actioned (because there are insufficient funds)

Figure 6 shows the object-state diagram. Only the part of the protocol you have discovered is shown

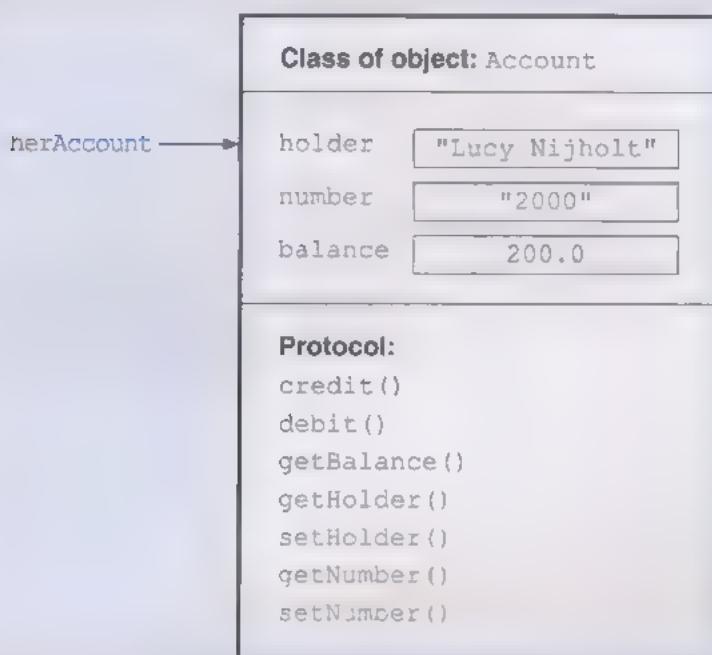


Figure 6 Object-state diagram for Account objects

The messages you have used so far are credit(), debit(), getBalance(), getHolder(), setHolder(), getNumber(), setNumber(). Note that, as in the Amphibian Worlds, the message used to find the value of an attribute has a name consisting of the name of the attribute preceded by the word get. This is a common convention in Java programming. Similarly, a message used to set the value of an attribute has a name based on the name of the attribute but preceded by the word

SAQ 15

Will Java treat MyAccount and myAccount as the same name?

ANSWER

No. The exact spelling and capitalisation matter in names of variables (and in names of messages and classes).

15.3 Collaborating Account objects

In this subsection you will be using the Accounts World to explore how objects in the Account class can collaborate

There are some messages in the protocol of the Account class that you have not yet tried to send. One of these is the message used to transfer money directly from one

Account object to another. The name for this message is `transfer()`. In Activity 14 you will use this message to transfer 300 from the account referenced by `myAccount` to that referenced by `herAccount`.

The `transfer()` message requires two arguments. In Java, when a message requires more than one argument, the arguments are listed between the parentheses of the message and are separated by commas. In the case of the `transfer()` message, the first argument is the Account object to which the money is to be transferred and the second argument is the amount to be transferred. For example, to transfer 300 from the receiving object to account `herAccount` you would use the message `transfer(herAccount, 300)`.

ACTIVITY 14

In the Accounts World, make sure you have two Account objects referenced by the variables `myAccount` and `herAccount`. If you do not have them, create them. Next, send a message to credit `myAccount` with 500.

Before you start, make sure you know the current balances in `myAccount` and `herAccount`. Now, try using `transfer()` to transfer 300 from `myAccount` to `herAccount`. (Click on the Protocol button to see how to use `transfer()`). Then inspect the two Account objects referenced by `myAccount` and `herAccount` to see if they have changed state in the way you would expect from the sense of the message.

DISCUSSION OF ACTIVITY 14

To transfer 300 between the accounts you use the message-send

```
myAccount.transfer(herAccount, 300)
```

The money has been transferred in the way you would expect. The answer from this message is true – the transfer was successful.

Exercise 5

The purpose of this exercise is for you to think about how the receiver of a message with name `transfer()` will carry out its responsibility to respond to this message. In the case where there are sufficient funds in the receiver account for the transfer to be actioned.

Imagine now that you are the object referenced by `myAccount`, in a state with a balance of 800. Imagine that a user of the system sends you the message `transfer(herAccount, 400)`, which requests you to transfer 400 to the account referenced by `herAccount`.

Imagine that you must carry out the **responsibility** to respond to this message, using a sequence of messages. To achieve your goal, you can send any message you like (except `transfer()`) to any Account object. To solve the problem, try to break it up into stages. What would a person do to carry out the same responsibility step-by-step? Try to find a message to help you carry out each stage. Draw a **sequence diagram**, like the one in Subsection 4.3, to help you solve the problem and to illustrate your solution. Your diagram should include the user and any relevant objects. Fill in a table like the following one to show in turn each receiver, each message including any arguments and message answers, if relevant, of any messages you need to send to satisfy your responsibility.

Strictly speaking, `transfer()` is not a message. It is only a message name. But most programmers say things like this for simplicity. This habit is fine provided that you make sure you are clear about the difference.

Receiver	Message	Message answer

Hint You may need to send a message to yourself as a necessary step in discharging your responsibility.

Solution

Just two messages are required. Note that the first message, debit(400), must be sent to yourself in your role as the object myAccount.

```
myAccount.debit(400)
herAccount.credit(400)
```

These two messages can be analysed in tabular form as follows.

Receiver	Message	Message answer
myAccount	debit(400)	true
herAccount	credit(400)	none

In Figure 7 the three vertical lines represent the user and the two objects myAccount and herAccount. Objects are drawn as vertical lines so that messages sent from one object to another can be shown clearly in order down the page. Bold arrows represent events. The sequence diagram shows the following steps. Read from left-to-right, the user first sends the message transfer(herAccount, 400) to myAccount. To satisfy this responsibility, myAccount first sends the message debit(400) to itself. Next, myAccount sends the message credit(400) to herAccount. This is all that myAccount has to do to discharge the responsibility it took on by accepting the message transfer(herAccount, 400).

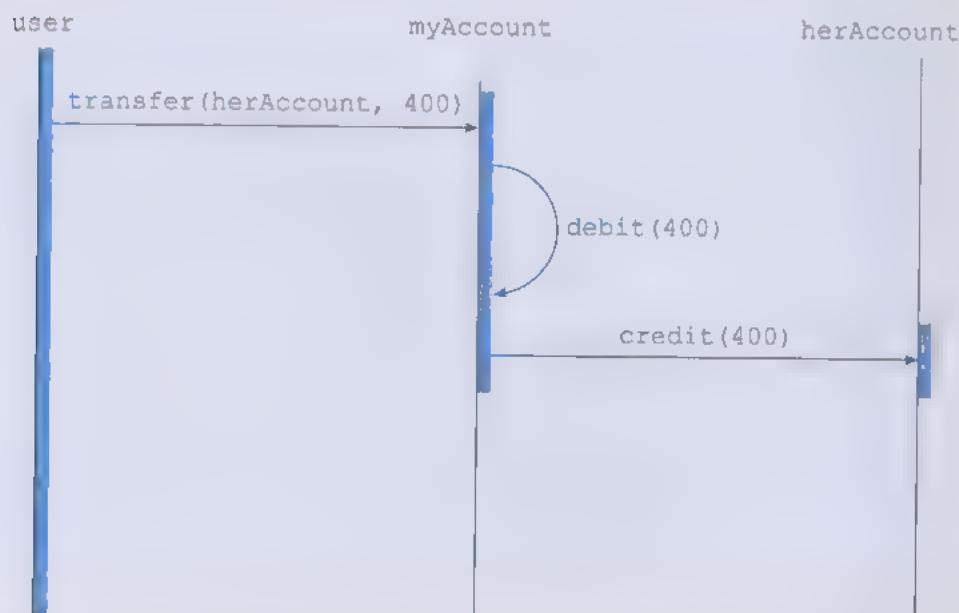


Figure 7 A sequence diagram for the message-send `myAccount.transfer(herAccount, 400)`

We should emphasise that we are *not* saying that the `transfer()` message is always equivalent to a pair of messages using `debit()` and `credit()`. It will not be equivalent in cases where the receiver of the `transfer()` message has insufficient funds for the transfer. In more detail, what happens when `myAccount.transfer(herAccount, 400)` is executed is that `myAccount` sends itself a `debit(400)` message and only if the message answer is true does it then send `herAccount` the message `credit(400)`.

Contrast this with the message `frog1.sameColourAs(frog2)`, where the receiver (`frog1`) always sends itself a message using `setColour()` after getting the colour of `frog2` by sending `frog2` a `getColour()` message. You will be able to see how this is done at the level of code once you move on to later units, where methods (Unit 4) and conditions (Unit 5) are introduced.

Thus, if you were the object referenced by `myAccount`, with a sufficiently large balance, and you received the message `transfer(herAccount, 400)`, you would send messages to appropriate receivers as follows

- 1 `debit(400)` to yourself
- 2 `credit(400)` to `herAccount`

There is a simple way of checking that this scheme works in your real-life role as user (as opposed to your previous make-believe role as the object referenced by `myAccount`) you could now try sending these two messages. If you do it this way yourself the final state of affairs should be exactly the same as if you just sent the message `transfer(herAccount, 400)` to the object referenced by `myAccount`, and thus requested it to take the responsibility.

ACTIVITY 15

In the Accounts World, make sure you have two `Account` objects referenced by the variables `myAccount` and `herAccount`. If you do not have them, create them. Ensure that `myAccount` has a balance of at least 400. Then execute the following two messages—send one at a time in the Code Pane—and then inspect the objects to look at the resulting state of affairs.

```
myAccount.debit(400);
herAccount.credit(400);
```

DISCUSSION OF ACTIVITY 15

The effect on the final state of the objects is exactly the same as sending a single message `transfer(herAccount, 400)` to the object referenced by `myAccount`, requesting it to take responsibility for the whole transfer. We studied this example in Exercise 5.

Whilst Exercise 5 may seem a little like a game, it is in fact an accurate description of how an `Account` object discharges its responsibility of responding to a message `transfer()` when there are sufficient funds for the transfer.

The receipt of the message `transfer()` results in the `Account` object, which is the receiver, sending two messages (without any human intervention).

- 1 The receiver sends a `debit()` message to itself. The argument to `debit()` is the amount specified as the second argument of the `transfer()` message.

- 2 The receiver sends a `credit()` message to the `Account` object that is specified in the first argument of the `transfer()` message. The argument to `credit()` is the same amount that was specified in the second argument in the original `transfer()` message and used in the `debit()` of step 1

We say that this is an example of an object discharging its responsibility by *collaborating* with other objects by sending them messages. We also say that the objects that the receiver collaborates with are its helpers in this context

Exercise 6

You have now seen two sequence diagrams one in Subsection 4.3 and one in the solution to Exercise 5. Looking at these diagrams, what interesting similarities and differences can you see between the way the following two lines of code are carried out?

```
frog1.sameColourAs(frog2);
myAccount.transfer(herAccount, 400);
```

Solution..

This is an open-ended question. Many answers are possible. One or two possible answers are noted below. Your answers may be different, but nevertheless correct.

Similarities

- ▶ Both involve collaboration between two objects
- ▶ Both involve an object sending a message to itself
- ▶ Both original responsibilities are discharged by the receiver by using exactly two messages

Differences

- ▶ In the frog example, a message answer becomes a message argument
- ▶ In the account example, the message arguments in both of the messages used to discharge the responsibility are taken directly from the message requesting the transfer

5.4 Recap of terminology

At this point it is useful to review some of the terminology to do with messages that you have learnt.

The receiver is the object to which a message will be sent. The name of the message must be one of those contained in the protocol of the receiver's class, otherwise the message send will not complete. The arguments are the pieces of information required, the message; some messages require no further information, and some require one or more pieces of information.

So, for example, in the case of the message-send

```
myAccount.credit(7)
```

`myAccount` is the receiver, `credit()` is the message name and `7` is the argument.

Finally some messages result in a message answer being returned.

Exercise 7

Fill in the following table for the message-send

`herAccount.transfer(myAccount, 200)`

Receiver	<i>herAccount</i>
Message	<i>transfer</i> (<i>myAccount</i> , 200)
Message name	<i>transfer</i>
Argument(s)	<i>myAccount</i> , 200
Message send	<i>herAccount.transfer</i> (<i>myAccount</i> , 200)

Solution.

Receiver	<code>herAccount</code>
Message	<code>transfer(myAccount, 200)</code>
Message name	<code>transfer()</code>
Argument(s)	<code>myAccount, 200</code>
Message-send	<code>herAccount.transfer(myAccount, 200)</code>

Exercise 8

Decide whether each of the following statements is true or false. If false, say why.

- ▶ All messages consist of a *name* and an *argument*
- ▶ An object is associated with a particular class
- ▶ A message is an instance of a class

Solution.

- ▶ False Some messages have no arguments, some have more than one argument
- ▶ True
- ▶ False Messages are not objects, and so they are not instances of a class

SAQ 16

A message may

- change the state of an object,
- make an object do something without changing its state,
- get back some useful information from an object
- cause an object to send a message to another object
- cause an object to send a message to itself.

Give an example of a message from this unit to illustrate each effect that a message can achieve in the list above.

ANSWER...

Effect	Example
(a) change the state of an object	<code>left()</code>
(b) make an object do something without changing its state	<code>jump()</code>
(c) get back some useful information from an object	<code>getColour()</code>
(d) cause an object to send a message to another object	<code>sameColourAs(frog2)</code> – the receiver sends <code>getColour()</code> to the argument
(e) be used by an object to send a message to itself	frog1 changes its own colour when carrying out actions in response to <code>frog1.sameColourAs(frog2)</code> . The name of the message sent is <code>setColour()</code> .

SAQ 17

Give your understanding of the following terms and their link with objects in the Glossary (No answer to this question is given)

argument attribute class message receiver receiver class state subclass

refine this

6

Summary

After studying this unit you should understand the following key ideas.

- ▶ The values of an object's attributes constitute its state
- ▶ An object's behaviour is determined by how it responds to the messages it understands (its protocol)
- ▶ The behaviour of an object in response to a message may be dependent on its state. An example of such state-dependent behaviour is the behaviour exhibited by HoverFrog objects when sent the upBy() message
- ▶ Objects are organised into classes. Objects belonging to the same class (instances of the class) have the same set of attributes and respond to the same set of messages responding to each message in the same (but often state-dependent) manner. Classes are can be thought of as templates or prototypes for creating objects
- ▶ When an object is created it has an initial state (its attributes have initial values). All instances of the same class have the same initial state
- ▶ A class may have subclasses. An instance of a subclass has all the attributes and protocol of the parent class (the superclass), but the subclass may add to them.
- ▶ A subclass may modify the response to a particular inherited message, so that an instance of the subclass will respond to that message in a different way to an instance of the superclass. Furthermore, it is also common for instances of unrelated classes to have the same message in their protocols, and instances of those classes may or may not respond differently to that message. Such messages are termed polymorphic messages
- ▶ Messages may return a message answer and/or change the state of a receiver or do neither. For example, the message getColour() merely returns the colour of the receiver whereas setColour() changes the value of the colour attribute. In the protocol of Frog objects, jump() neither changes the object's state nor returns a message answer
- ▶ Some messages require arguments – extra information that is required for the message to make sense. For example, the upBy() message requires an int argument specifying what position the receiver should move to, as in the following message-send. `hoverFrog1.upBy(2)`
- ▶ It is common for the protocol of an object to include pairs of messages to provide access to each of its attributes. A getter message and the corresponding setter message together form what is called a pair of accessor messages. For example, in the protocol of Frog objects, the message getColour() returns the value of the receiver's colour attribute, and setColour() sets (changes) the receiver's colour attribute
- ▶ A message may cause the receiver to send a message to another object to help it carry out the behaviour required. For example, the message-send

```
frog1.sameColourAs(frog2)
```

results in frog1 sending frog2 a getColour() message in order to determine the colour of frog2. This behaviour is termed collaboration.

- ▶ A message may cause the receiver to send a message to itself. For example, the message-send

```
frog1.sameColourAs(frog2)
```

results in frog1 sending itself the setColour() message

LEARNING OUTCOMES

After studying this unit you should be able to

- ▶ use appropriately the terms: object, message, protocol, state, attribute, argument class, instance, receiver, message-send, message answer, message name, getter message, setter message, subclass, superclass, initialisation, polymorphism;
- ▶ use the microworlds in the Amphibian Worlds application to send messages to Frog, HoverFrog and Toad objects, including messages which require arguments;
- ▶ use the Accounts World programming tool, to create and send messages to Account objects, including messages which require arguments;
- ▶ inspect the state of objects;
- ▶ describe and explain the superclass-subclass relationship between the Frog and HoverFrog classes;
- ▶ describe the role of accessor messages in an object's protocol;
- ▶ discuss how two or more objects can collaborate to perform a task, and draw a sequence diagram to depict the interactions between the objects in the form of messages and message answers.

Glossary

accessor message The general term for either a **setter** or a **getter message**.

argument Extra information supplied with a **message**. For example, when requesting a Frog object to change its colour to that of another Frog object, it is necessary to provide that other Frog object as an argument. This is seen in the **message-send** `frog1.sameColourAs(frog2)`.

A message can have zero, one or more arguments.

There is no argument in the message `getColour()`.

The message `setColour(OUColour.PURPLE)` has one argument (namely `OUColour.PURPLE`) supplying information on which colour is to be chosen.

Two arguments (`yourAccount` and `50`) supply information in the message `transfer(yourAccount, 50)`.

attribute Some property or characteristic of an **object**, such as position for Frog objects, or balance for Account objects.

attribute value The current value of an **attribute**. For example, a Frog object has the attributes colour and position. The attribute colour of a particular object might have the value `OUColour.BLUE` and the attribute position might have the value `1`.

behaviour This term is used to describe the way an **object** responds to the **messages** in its **protocol**.

class A class is a template that serves to describe all instances (objects) of that class. It defines what **attributes** the objects should have and their **protocol** – what messages they can respond to.

Instances of the same class have the same attributes, which are initialised in the same way. They have the same **Instance** protocol and respond in the same way to each message.

getter message A message that returns as its message answer the value of one of a receiver's attributes. See **setter message** and **accessor message**.

initialisation The **state** of an **object** when it is first created depends on its initialisation.

inspector An inspector is a tool used in M255 to look at the internal state of **objects** in a system. It lists the **attributes** of an object and displays their current values.

instance An **object** that belongs to a given **class** is described as an instance of that class.

message A message is a request for an **object** to do something. The only way to make an object do something is to send it a message.

For example, the position of a Frog object changes when it is sent the message `left()` or `right()`; to obtain information on the value of a Frog object's colour attribute, you send it the message `getColour()`.

message answer When a **message** is sent to an **object** then, depending on what the message is, a message answer may be returned. A message answer is a value or an object; it is not a message.

Sometimes a message answer is used, sometimes it is ignored. A message answer may be used subsequently as the receiver or argument of another message.

Enquiry messages (getter messages) often return the value of an **attribute**, as with the message `getColour()`, which returns a value such as `OUColour.GREEN`.

message name The name of a **message** does not include any arguments. For example, the name of the message `left()` is `left()`, and the name of the message `upBy(6)` is `upBy()`.

message-send The code that sends a message to an object – for example, `frog1.right()`, which consists of the **receiver** followed by a full stop and then the **message**.

object An object is a software component that has a unique identity and responds to **messages**. Each object has **state** and responds to a particular set of messages (its **protocol**). Thus a Frog object (which has little resemblance to a real-world frog) holds information on its position and colour as values of its **attributes** `position` and `colour`.

object-state diagram An object-state diagram represents an **object**. It shows the **class** of the object, its **state** in terms of attribute values, and its **protocol**.

parameter A synonym for **argument**.

polymorphism Any **message** to which **objects** of more than one **class** can respond is said to be polymorphic or to show polymorphism.

For example, both Toad and Frog objects respond to the message `left()`, but with different behaviours. They also respond to the message `green()`, with identical behaviours.

protocol The set of **messages** an **object** can respond to (understands).

receiver The **object** to which a **message** is sent.

sequence diagram A diagram that depicts the interactions between objects, in the form of **messages** and **message answers**.

setter message A message that sets the value of one of a receiver's attributes. See **getter message** and **accessor message**.

state The values of the **attributes** of an **object** constitute its state. The state of an object can vary over time as the values of its attributes change.

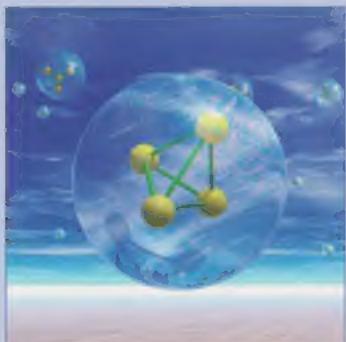
subclass A subclass is a new **class** defined in terms of an existing class (its **superclass**). Instances of a subclass have all the attributes that instances of the superclass have, but may have additional attributes. The protocol of the subclass includes (has at least all the messages of) the protocol of the superclass, but may define additional messages.

For example, HoverFrog is a subclass of Frog. The protocol of HoverFrog objects includes that of Frog objects and has, in addition, the messages `upBy()` and `downBy()` to which Frog objects cannot respond. HoverFrog objects have all the attributes of Frog objects (`colour` and `position`) and an additional attribute – `height`.

superclass If B is a **subclass** of A, then A is the **superclass** of B.

Index

A	M	R
accessor message 23	message	responsibility 35
argument 17	accessor 23	
B	answer 23	
behaviour 8	get 23	
state-dependent 14	name 18	
C	set 23	
class (in programming) 8	message-send 32	
collaborating objects 23, 26	O	
G	object collaboration 23, 26	
getter message 23	object creation 29	
I	object-state diagram 27	
initialise 8	P	
instance 6	polymorphism 10	



M255 Unit 2
UNDERGRADUATE COMPUTING
**Object-oriented
programming with Java**

Block I

- Unit 1 Object-oriented programming with Java
- Unit 2 Object concepts
- Unit 3 Variables, objects and representations
- Unit 4 An introduction to methods



M255 Unit 2
ISBN 978 0 7492 5494 0



9 780749 254940